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# An Enhanced Inter-Domain Communication among MANETs through selected Gateways

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*Abstract*— **In Mobile Ad-hoc Networks(MANETs), enabling communication among different domains is becoming one of the areas of research topics as Border Gateway Protocol (BGP) is not adequate to support MANETs (Mobile Ad-hoc Networks). BGP does not scale to mobile and topological environment [14]. So there is a need to develop an efficient inter-domain routing protocol for heterogeneous MANETs. This is to improve the connectivity of the nodes present in different domains. Gateways as special nodes must be used for Inter-Domain communication which acts as bridge between domains and they play a major role in route updation, protocol translation and policy enforcement. Due to mobility of nodes, gateway functionality must be assigned dynamically for nodes as static assignment will not be effective. In this paper an attempt has been made to select minimum number of gateways. Nodes in different domains can communicate through the selected gateways. Data transmission occurs through minimum hops (minimum geographical distance) and least load path.**

*Index Terms*— **MANET, Gateway, Inter-Domain Routing, Graph**

## I. Introduction

### A. Mobile Ad- hoc Networks

Mobile Ad-hoc Network is characterized by self configuring, decentralized, high dynamic topology. Each node acts both as a host and a router. MANET is represented by distributed system with wireless mobile nodes which move freely and self organize forming ad-hoc network topologies without pre-existing infrastructure. So each node acts both as a host and as a router. Communication is performed through multi-hop routing. Traditionally we find MANET applications in tactical networks but now technologies like IEEE 802.11, Hyperlan enable commercial deployments apart from military domain. For faultless connectivity of nodes to achieve a mission like military operations, disaster recovery, rescue operations, conferences, and for vehicular ad-hoc networks [1] there is a need to develop an efficient Inter-Domain routing protocol.

### B. Inter-Domain Routing

In some situations, multiple MANETs belong to different organizations or domains need to communicate with each other to share information, to alert other parties by delivering commands [6]. This form of Inter-domain networking should enable communication for different organizations with heterogeneous networking technologies from routing layer (OLSR, AODV) to physical layer (2.4 GHz – 54 GHz) by preserving their policies [7]. There would be no clear boundaries for MANETs as arbitrarily they can split or merge [2]. Gateway is the key component in the inter-domain networking which act as bridge between domains. Gateways collect and distribute Inter-Domain routing information. Also they need to perform protocol translation as different domains employ different routing protocols [11]. Inter-Domain routing is a fundamental mechanism to support the inter-operation among multiple network domains. Due to mobility of nodes, routing is one of the key challenges faced by researchers.

### C. Challenges in MANETs

The dynamic nature of network topology and the resource constraints makes MANET routing a tedious process. Static gateway assignment method would not be effective as nodes are mobile. Also due to nodes mobility or wireless channel variation, connectivity might be lost. If all nodes are assigned the role of gateway, it leads to power consumption and generates more traffic. Least number of gateways might not be able to maintain reliable connectivity. So due to frequent changes in topology, instead of making every node act as gateway it is required to assign the role of gateway dynamically to few nodes in order to sustain the connectivity among domains[11]. Then nodes from one domain can communicate to the nodes of other domains.

### D. Assumptions and Notations

All the nodes are assumed to be Global Positioning System (GPS) enabled. G = (V, E) is a connected graph which is complete topology of MANETs, where V is set of all the nodes and E is set of logical links. When few nodes move away from a domain, graph is partitioned, i.e. set V as P (set of partitions), it represents the set of disjoint connected sub graphs of G, where P is connected and has the disjointness property.

Given a connected graph G = (V, E) and collection of disjoint connected sub graphs P of G [11], the goal is to find a set of gateways N. Nodes use these selected gateways to communicate to other nodes of different domains. An attempt has been made in this work to select minimal number of gateways. According to MANETs requirement, there could be more than one gateway in each domain. Based on geo-location, Gateway calculates the geo-distance between itself and its neighbors. Any source wants to communicate to a destination of the other domain, Gateway tries to transmit




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Int. J. on Recent Trends in Engineering and Technology, Vol. 9, No. 1, July 2013

the data by selecting minimum hops path and least-load path. A subset $N \subseteq V$ is a gateway assignment such that $G_{dm}[N] = (P, L_{dm}(P, N))$ is connected which is the partition level graph. If a node is in N, it is assigned as an active gateway.

## II. Related Works

Chi-Kin Chau and associates in Ref. [3] have designed IDRM [Inter-Domain routing protocol for MANETs] which supports opaque interoperations among multiple domains of MANETs. It needs special nodes as gateways, whose role is to handle inter-domain routing and to bridge any technical stream that exists between MANETs at physical, MAC and network layers. The main focus of this paper is the inter-domain routing functions of the gateways. Also authors have identified the challenges of inter-domain routing of MANETs. IDRM can support network operators to specify routing policies similar to BGP. Biao Zhou and associates in Ref. [4] proposes Cluster-based inter-domain routing protocol where packets to remote nodes are routed via cluster-head advertised routes. Cluster (subnet) is defined a priori or evolves dynamically by the affinity of geography, motion or tasks. For Ref. [4] to work, few assumptions are made. Also author mentions that cluster–based networking is based on geographic proximity of the nodes. So it is more appropriate for stationary rather than mobile nodes.

Biao Zhou and associates in Ref. [5] have proposed ways to optimize Geo based Routing protocol and to reduce control overhead. Two metrics are considered–packet delivery ratio and control overhead. Radio range of 375 m is taken for evaluation. GIDR in Ref. [5] achieves scalability by using geo-routing packet forwarding scheme and clustering scheme. It handles frequent network topology changes by employing group affinity during cluster formation. The protocol assumes all the nodes are equipped with GPS. "Geo-assisted Multicast Inter-domain Routing (GMIDR) Protocol for MANETs" in Ref. [6] is a multicast Inter-Domain routing protocol and till now only a few multicast protocols are designed for inter-domain networks. Here two domains are used in simulation and metrics i) packet delivery ratio and ii) control overhead are evaluated.

InterMR in Ref. [7] is an attribute based protocol, proposing attribute based address scheme, which handles heterogeneity and dynamics of MANETS. It is an extension of Ref. [3] work. It assumes all the nodes in a MANET employ same wireless PHY/MAC and routing protocols, governed by single administrative entity. Also it assumes that gateways in each MANET are fixed, each MANET has same number of nodes & gateways with same transmission radius r and mobility model. Karthikeyan.C and associates in Ref. [8] proposed a domain based hierarchical routing for large heterogeneous MANET, which divides the large heterogeneous network into homogeneous domains. Inter-Domain communication is carried out via border nodes. This protocol is based on beacon protocol, independent of intra-domain routing which enhances routing by reducing overhead and enhancing data delivery.

Chi-Kin Chau in Ref. [9] gives potential solutions to enable Policy-base interactions. The author believes that the future study of policy semantics with interaction between policy and MANET dynamics are important to practical deployment of inter-domain routing in MANETs. Alan J. Ford and associates in Ref. [10] describes the functionality required at gateways / routers to provide interaction with each other and with the IGP to minimize the need for knowledge of external routing topology. In fact authors have stated some potential solutions to open issues on interactions between intra and inter-domain MANET routing protocols also identified future areas of work to asses these solutions. Starsky.H. Y.Wong et al., in Ref. [11] have formulated the gateway assignment problem subject to the connectivity constraint and show its NP-completeness. Then they have proposed a 2-approximation polynomial-time algorithm and empirically show that it performs empirically close to the optimal solution in average case. Next they have extended the centralized approximation algorithm to distributed versions with different levels of cooperation among the domains. You Lu et al., in Ref. [12] have proposed I-GIDR (Improved Geographical Inter-Domain Routing Protocol) which has several techniques to improve geo-based inter-domain routing protocol for MANETs. One key innovation is a new proposed gateway election algorithm that accounts for neighbor's number and distribution to select a gateway that can adapt to multiple domain scenarios. Another key innovation of the paper is neighbor priority, a concept based on the geographical distribution and density of neighbors. Using neighbor priority concept they optimized the geo-based routing protocol by reducing control overhead. For seamless inert-domain routing across different MANETs, authors in Ref. [13] have introduced a topological aware protocol which implements fully distributed dynamic gateway assignment mechanism by improved performance up to 200% when compared to static mechanism.

## III. Proposed Work

### A. Overview

Figure 1 shows the dynamic change in network topology. If new nodes join, or if nodes move away from a domain, domain is partitioned. Hence gateway has to be selected to sustain the connectivity of domains (or partitions $P_i$). The selected gateways in figure 2 can help nodes of different domains communicate with each other. All the figures are drawn using CorelDraw software.

For the multiple domains to communicate with each other gateways are the key components. The gateways act as a bridge between the domains and play a very important role in the inter-domain communication. For the communication to happen among the incompatible domains, the gateways should have multiple interfaces. Gateways must be selected carefully to assure the efficiency and accuracy of communication between domains.

The proposed architecture consists of a set of domains (partitions) which need to communicate with each other




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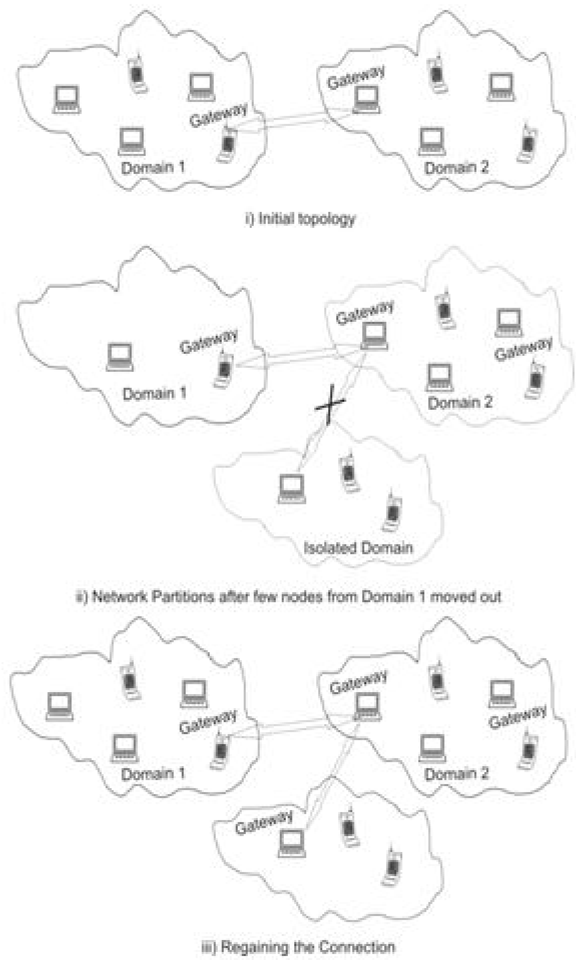


Figure 1: Example of topology changes of domains

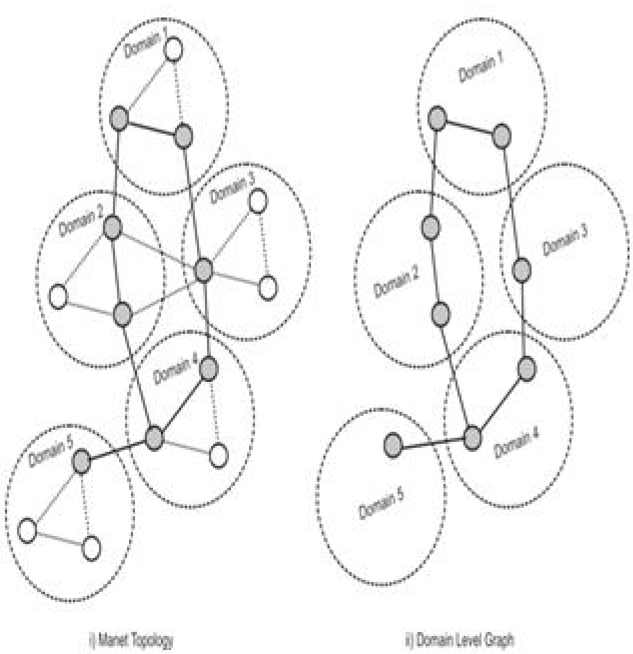


Figure 2: Example of minimal gateway selection N. Marked nodes are gateways

through a selected gateway. The gateways are selected by using the algorithm given in section IV. All the potential gateway nodes update their routing table with the information about their neighbors. While updating, each node calculates least-load path to the neighboring nodes of other domains as given in the equation (2). Then among these selected nodes, final set of gateways is selected using equation (6). When a source node from any domain, wants to communicate to any other node (destination) of other domain, it first sends the data to the gateway of its domain. In turn gateway forwards the data by considering minimum geographical distance as given in equation (1) and least load path to gateway of destination node present in other domain. Finally data reaches destination node through its gateway.

*B. Estimation of metrics*

The minimum number of hops is calculated by using the below formula,

$$H(s,d) = \begin{cases} \min \{H(p) : s \xrightarrow{p} d\} & \text{if there is a path from } s \text{ to } d \\ \infty & \text{otherwise} \end{cases} \quad (1)$$

where p is a path, H is the shortest-path geographical distance from source (s) to destination (d) which is the sum of its links in any path p.

Now this shortest path distance is used to find the least load path from the below equation,

$$L(s,d,h) = \begin{cases} \min \left\{ L(h) : s \xrightarrow{p} d, h : H(s,d) \right\} & \text{if there is a path from s to d} \\ \infty & \text{otherwise} \end{cases} \quad (2)$$

The value of domain balance as in Ref.[12] is given by

$$B = \frac{(\sum xi)^2}{(n * \sum xi^2)} \quad (3)$$

where n is total number of domains. xi is as in equation (4). The above equation determines that all the nodes are receiving the fair amount of network resources.

$$xi = \frac{\text{number of neighbours in domain } i}{\text{number of members in domain } i} \quad (4)$$

In I-GIDR [12] the neighbor number and neighbor distribution are considered to achieve higher degree of connectivity. The gateway node is selected in such a way that the gateway will have more number of neighbor nodes to connect more inter-domain nodes for the transmission of the routing information. Among all the nodes, the transmission efficiency is calculated by the equation

$$R = n_d / N \quad (5)$$

where R gives neighbor ratio which is the ratio of number of neighbors ($n_d$) to the total number of nodes (N) in the network. Gateway must have more number of neighbors to connect to, as it makes transmission of routing information more efficient.

Considering (3), (4) and (5), finally gateways can be minimized based on the below equation


DOI: 01.IJRTET.9.1.13

$$\max[\alpha \times B + (1-\alpha) \times R] \quad (6)$$

The parameter α value is selected as 0.6 which is a coefficient to control weight of each factor as in Ref. [12]. The result of gateway selection could be changed by modifying "α". Here the value of α is selected as in Ref. [12]. To select more than one gateway in a domain, values in sequence from high to low are selected.

After the gateway selection, for data transmission, gateways calculate minimum distance and least-load path using

$$H(s,d) < th_s \text{ and } L(s,d,h) < th_l \quad (7)$$

Here certain value of threshold is fixed to the shortest path () and least load path ().

The algorithm IDC (Inter-Domain Communication) given below is executed to adapt to network topology to select gateways.

## IV. Algorithm

### *A. Algorithm IDC: Input (G, P), Output N*

1: n ← Ø
2: repeat
3: for each n ∈ V do
4: X(n) ← n
5: for each n ' ∈ $Nb^{itd}$(n) do
6: if Comp ($G_{dm}$[N]) > Comp ($G_{dm}$[N ∪ X(n)]) then
7: X(n) ← X(n) n '
8. for all X(n), update L (n, n ' )
9: end if
10:end for
11: set W (n) =Comp ($G_{dm}$[N ]) – Comp ($G_{dm}$[N {n} X(n)])
12: end for
13: $V^*$ ← argmax $_n$ ∈ V W(n)
14: $n^*$ ← argmin $_n$ ∈ $V^*$ |X(n)|
15: if W(n*) > 0 then
16: N ← N X(n *)
17: end if
18: until W(n*) > 0
19: return N

The above algorithm is to make sure that the selected nodes as gateways will always give the largest decrease in the number of disjoint components with the smallest number of gateway assignment in each step. For each node n ∈P, V(n) denotes the same nodes that of in the same domain as n, $Nb^{itd}$(n) denotes the inter-domain neighbors of n. In each iteration of IDC, it selects the node that needs minimum number of new gateway so that it helps to connect the maximum number of disjoint components. The X(n) mentioned in line 4 refers to the number set of new nodes needs to assign into N (i.e., to become gateways) to reduce the number of disjoint components in $G_{dm}$[N]. The value of W (n) defined in line 11 refers to the number of disjoint components that can be connected if {n} ∪ [X(n)] are assigned into N. The rest of the notations used in the above algorithm are described below; N is the subset of nodes as a gateway assignment, P is the collection of disjoint connected sub graph of G, $Nb^{itd}$ is the set of inter- domain neighbors of node n, Comp is the number of disjoint component in a graph G, $G_{dm}$[N] is the domain level graph,.

## V. Simulation Results

The proposed work is evaluated through NS2 [10] simulation. The simulation settings are summarized in the following table.

Table 1: Simulation Settings

| | |
|---|---|
| Mobile Nodes | 50 |
| MAC protocol | 802.11 |
| Propagation Model | Two Ray Ground |
| Area Size | 1200 X 1200 |
| Simulation Time | 50 seconds |
| Radio Range | 250m |
| Gateway nodes | 8 |
| Traffic Source | CBR |
| Packet Size | 512 |
| Data Rate | 250Kb |
| Mobility Model | Random Way Point |
| Speed | 5m/s to 25m/s |
| Traffic Flows | 1,2,3 & 4 |

### *A. Performance Metrics*

The performance of the proposed work is evaluated according to the following metrics.

Average end-to-end delay**:** The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

Average Packet Delivery Ratio**:** It is the ratio of the number of packets received successfully to the total number of packets transmitted.

Drop: It is the average number of packets dropped during the transmission.

Throughput: It is the average rate of successful message delivery over a communication channel.

The comparison of this work is made with the Improved Geo based Inter-Domain Routing (IGIDR) [12] protocol. The simulation results are given in the next section.

### *B. Results Based on Speed*

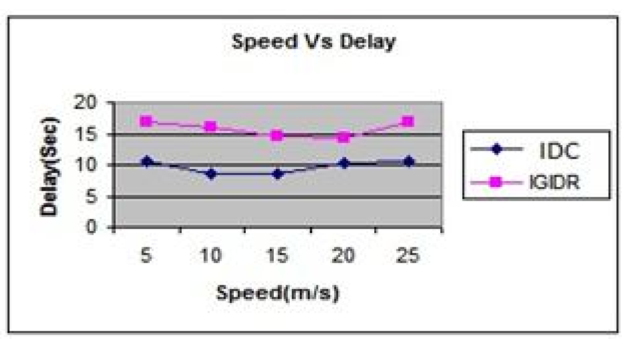


Figure 3: Speed Vs Delay




DOI: 01.IJRTET.9.1.13

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Int. J. on Recent Trends in Engineering and Technology, Vol. 9, No. 1, July 2013


Figure 4: Speed Vs Delivery Ratio

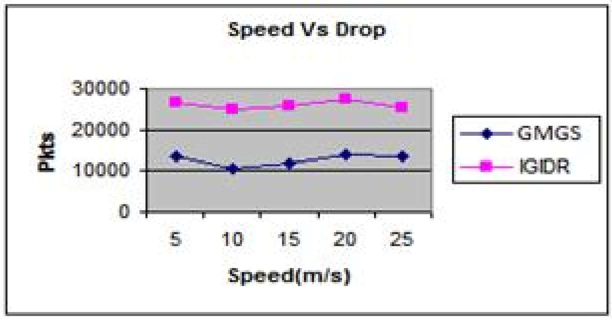


Figure 5: Speed Vs Drop

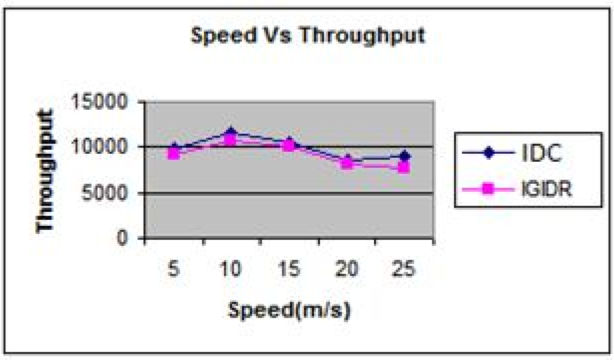


Figure 6: Speed Vs Throughput

In figures 3 to 6, nodes speed is varied. In figures 7 to10, the CBR traffic flows is varied. From figure 3 and figure 7, it is shown that the delay of the proposed work is less than the existing IGIDR protocol. From figures 5, and 9, it can be seen that the drop rate is low. From figures 4, 6, 8 and 10, delivery ratio and throughput are higher than the existing IGIDR protocol. This is because, as the speed is varied, topology is changed. Minimal number of gateways is selected which reduces the traffic as the data is sent using minimum hop and least-load path through selected gateways.

### *C. Results Based on Flows*

In the second set of experiments the CBR traffic flows is varied from 1 to 4.

## Conclusion

In this paper a Minimal Gateway selection method to interconnect the MANETs is proposed which can be used to assist the geo-based inter-domain routing protocol. For gateway selection, the metrics like node density and neighbor nodes are considered. Two other metrics - number of hops

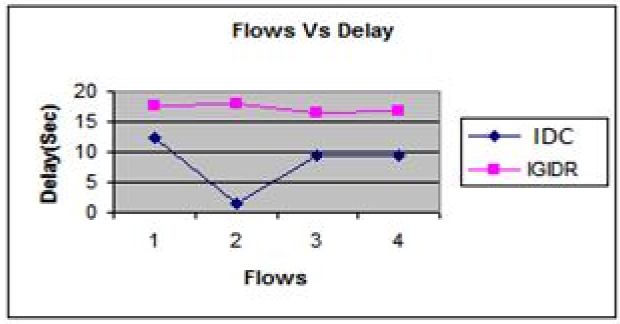


Figure 7: Flows Vs Delay

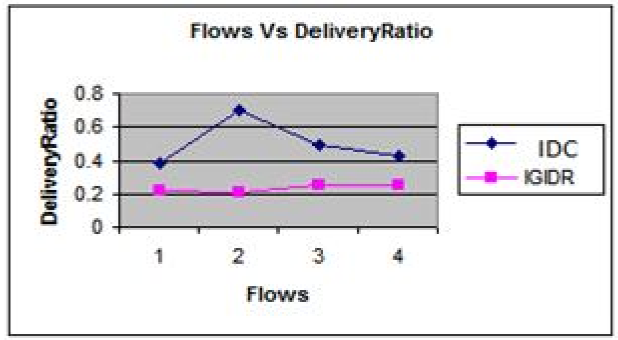


Figure 8: Flows Vs Delivery Ratio

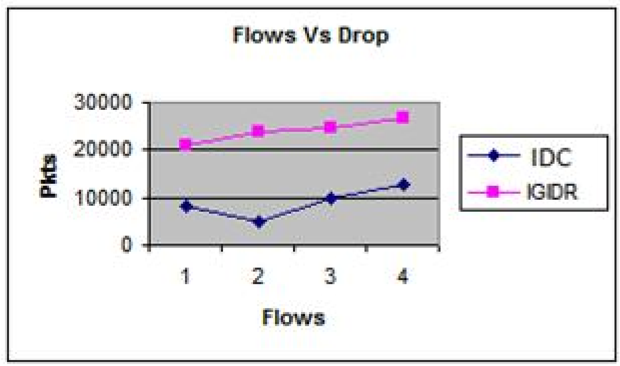


Figure 9: Flows Vs Drop

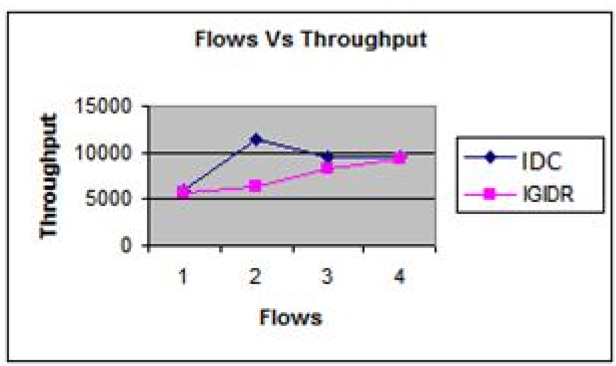


Figure 10: Flows Vs Throughput

and least- load path are used for data transmission from a source node in one domain to a destination node of different domain. By simulation results, it is shown that the proposed method attains high throughput, packet delivery ratio and less delay.




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Int. J. on Recent Trends in Engineering and Technology, Vol. 9, No. 1, July 2013

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